Standardizing Specification Language: IEEE Std 1515-2000

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Abstract **A newly published standard, IEEE Std 1515-2000, is introduced. It intends to standardize on specification language. It does not intend to specify or to enforce "a standard specification." Specific examples illustrate how it was written and how it is supposed to be used. It also shows the benefits that can be obtained from adopting the standard by the power electronics industry, including manufacturers, system developers, as well as academic institutions.**

1. Introduction

In the past two decades, the power electronics industry has experienced tremendous growth. For instance, switched-mode power supplies now occupy 95% of the market (compared to only 12% in the 1970's) and switched-mode motor devices are replacing traditional motor drives in virtually all applications. As with many maturing technologies, unprecedented growth creates a problem that hinders further growth. The problem is lack of a common specification language [1].

Lack of a common specification language creates confusion among industry manufacturers and systems developers. Different manufacturers and subsystem developers use similar terms to indicate different performance. This confusion not only hinders effective communication and the interchangeability among products, but also increases the cost and time for both development and procurement. This is particularly true for high-end customer designs, such as those intended for military and aerospace applications.

In 1998, the Power Sources Manufacturers Association (PSMA) issued a document [2] to enforce "disciplines" in units, symbols, and type setting in products specifications. However, definitions of common parameters and test methods, and test conditions were not pursued. To address this issue, the Department of Defense (DoD) Joint Task Force on Open Systems (OS-JTF) and the Standards Committee of the IEEE Power Electronics Society (PELS) undertook a joint effort in 1997. A small funding is provided through OS-JTF to sustain a general, loose umbrella organization known as Electronic Power Specification Standardization (EPSS Working Group). The primary goal of the EPSS is to promote specification standardization for the electronic power industry. The general objective is to improve clarity and understanding of power equipment specifications [3-7].

In the mean time, IEEE sponsored P1515 Working Groups was formed to draft specific standards. This paper is a progress report of the P1515 working group. The initial focus has been on standardizing electronic power system specification language. After three years of continuous work, the working group accomplished its mission in early 2000. The IEEE Standards Board subsequently published a standard, IEEE Std 1515-2000 [8], in September of 2000.

The purpose of IEEE Std1515-2000 is to standardize on specification language, not to specify, nor to enforce "a standard specification." A specification written in compliance with this language will ensure easy and precise understanding between manufacturers and users, without in any way limiting a manufacturer's ability to present features that are unique to their products.

This paper is organized as follows. Section 2 presents the reasons why the IEEE 1515 is needed. Section 3 gives discussions on what the IEEE 1515 is and what it is not. Section 4 shows a few common parameters defined in IEEE 1515. Section 5 indicates potential benefits that one can gain from using IEEE 1515. And Section 6 introduces a continuing effort by the EPSS Working Group and invites participation.

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2. The Need for a Standard Specification Language

Before the initiation of this work, there has been only limited agreement across the power electronics industry in terms of product design, performance specifications, or even the definition of basic terms in widespread use, such as for example output peak-to-peak ripple. This has often led to confusion particularly among OEM users of power modules who often must carry out their own full program of characterization tests on potential suppliers' products in order to have a set of comparable test results taken under comparable conditions and using comparable test methods. A more detailed discussion on the need can be found in [1].

Some examples of the type of problems that may occur, due to the absence of standard test methods, when trying to compare specifications and data sheets from different vendors are given here.

1. Different suppliers using different test methods to measure ripple voltage. Frequently, specifications with similar values can actually mean different performance. Test methods in use include:
   - Direct measurement of ripple voltage across the output pins of the UUT with an oscilloscope probe, using the shortest possible connections.
   - Measurement at the end of a 12 inch length of twisted pair wires with a 47uF capacitor directly across the measurement point
   - Measure with a 0.1uF capacitor across the output pins of the UUT

2. Input reflected ripple current may be specified with or without large external capacitors, with different values being recommended by different suppliers.
3. Datasheet parameters may be specified by one supplier at nominal input voltage and 25 C ambient, but another supplier may specify parameters applying over the full range of input voltage and ambient temperature
4. One supplier may define hold-up time from nominal input voltage whereas another defines hold-up time from maximum input voltage.

With any of these examples, it becomes difficult, if not impossible, to compare different datasheets directly. Furthermore, the product that appears to have the best performance may in fact not be the best or may even be the worst. Consequently, a lot of time and effort must be taken to gather test data using common test methods and test conditions. A widely accepted standard will avoid these types of difficulties.

3. What is IEEE Std 1515-2000?

The IEEE Std 1515 is a basically specification language, providing parameter definitions, test conditions, and test methods. It does not attempt to standardize the specification itself. It provides the basis that allows everyone to speak the same language on a level playing field.

The ground rules adapted in writing the standard were: 1) It is intended for practical use; 2) It includes only the most commonly used parameters; 3) It follows prevalent industry practice; and 4) It tries to streamline the parameters when there are divergences in industry usage.

The scope of the standard covers a broad range of DC-to-DC and AC-to-DC power systems up to 600Vdc and up to 20kW, intended for use with digital, analog and RF electronics.

The test methods are not created new, but are compiled from existing, prevalent methods already in use – the key benefit is in the agreement to standardize on a single definition or test method. Since these test methods are already in general use, the adoption of the standard should not require any redesign of existing product.

However, a manufacturer may wish to revise his datasheets where necessary to fully align with the standard and to re-exam their test methods. Consistency in data is important to end-users.

In general, specific quantities were avoided whenever it is possible in the parameter definitions, the test conditions, and the test methods. This is needed to ensure generality and hence potentially wide application. Specific quantities were specified only when they are the essential part of the definition, test conditions or test methods.

General discussions of EMC and EMI parameters were beyond the scope of a standard like this. Hence, detailed discursions were not pursued. Instead, basic parameters were defined or collected to guide engineers to perform a first-order check in their power labs before they send their units to EMC/EMI labs for formal EMC/EMI tests.

Environmental parameters were collected in the standard for easy reference. They intend to highlight, to engineers, what are important in qualifying a product. Engineers who desire a more detailed discussion are refereed to prevalent industry and military standards.

Mechanical parameters were limited to size, weight and form-and-fit functions. No parameters that were deemed "mechanical in nature" were included.

Example 1: Output Voltage Ripple

Output Voltage Ripple

Definition

The maximum ac voltage present on a dc or low-frequency ac voltage stated in peak-to-peak voltage. The intent is to characterize the residual component associated with the switching action at the output switching frequency (or twice the output switching frequency) (see Figure 1).

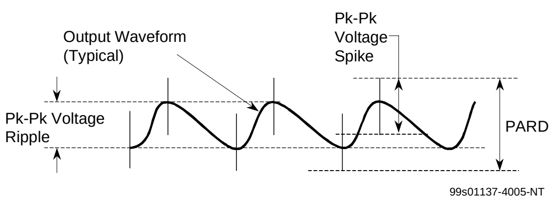

Figure 1. Typical output voltage ripple and spikes

Test Method

Connect the test setup shown in Figure 2. Use an oscilloscope with a differential input amplifier and measure differentially between the plus and minus output terminals of the UUT. Make sure the UUT is isolated from any other conducting surface.

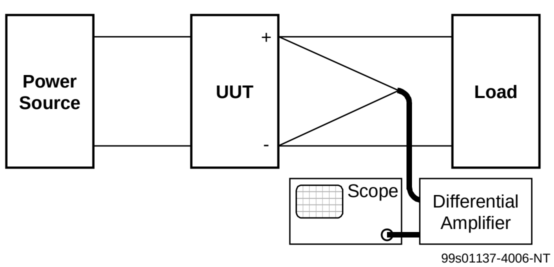

Figure 2. Output voltage ripple test setup

Other methods specified in 4.5.3 can also be used (and should be specified in the evaluation).

Test Condition

The operating temperature should be from minimum to maximum; the input voltage should be V_{min}, V_{nom}, and V_{max}; the load should be resistive, and should be I_{min}, I_{nom}, and I_{max}. The bandwidth of the scope should be at least 10 times the switching frequency."

Switching Spikes

Definition

Switching spikes are generated by commutations of load current among switching devices. Their duration is typically less than 1/10 of switching period, and their amplitude is expressed as a maximum peak-to-peak value.

Test Method

Test Method a) Refer to Figure . The ground lead of a voltage probe is removed to avoid getting any high-frequency pick-ups. Press the tip against "Out +" and the ground ring (band) against "Out -" of the UUT. Wrap the probe lead several times around a high µ core to minimize common-mode noise.

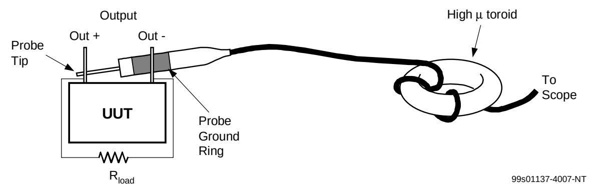

Figure 3. Measuring output voltage spikes – Method a

Test Method b) This method requires a simple set-up (a special probe). Refer to Figure . A coaxial cable is used to connect to a scope. A BNC "T" connector, terminated by a 50 Ω carbon resistor in series with a 0.68 µF ceramic capacitor, is used at one end connecting to a scope. At the other end, the BNC cable is split and connected to the output of the UUT.

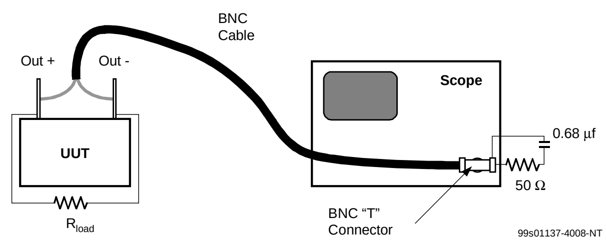

Figure 4. Measuring output voltage spikes – Method b

Test Method c) This method requires a capacitor of up to 1µF in value added at the probe tip when measurements are made in an unshielded environment. The added capacitance is less than 0.1% of the system output capacitance. Refer to Figure .

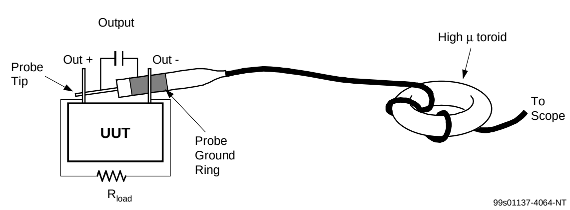

Figure 5. Measuring output voltage spikes – Method c

Test Condition
The operating temperature should be from minimum to maximum; the input voltage to the UUT should be V_{nom}, V_{nom}, and V_{max}; the load is resistive, and should be I_{min}, I_{nom}, and I_{max}. All measurements should be over a specified bandwidth that is at least 100 times the switching frequency.

Example 2: Overvoltage Response

Overvoltage Response

Definition

The protective action taken by a power supply in response to an overvoltage condition on its output, induced either by an internal fault or by the external application of an overvoltage condition. Overvoltage protection circuits may result in a cyclic shutdown/restart or a latched off condition. Latch off circuitry is typically used if the circuit is intended to protect against internal unit failures.

Overvoltage response is a condition in which the power supply output voltage, having reached an over voltage trip level, will be reduced to a quiescent safe voltage level. This voltage level may provide a false indication to the power supply output control circuitry, that the over voltage condition no longer exist, resulting in reinstatement of the prior overvoltage condition. Providing a latch to the power supply, after an overvoltage condition occurs, eliminates this from happening. A common practice to remove the latch, is to recycle input power. Non-latching overvoltage protection circuits should provide a fixed or minimum recycle time to prevent overstress due to rapid hysteretic cycling of the output and should control the reinstatement of the output voltage(s) to limit overshoot/undershoot.

Test Method

The measurement of overvoltage can have varying degrees of complexity dependent on the method of overvoltage implementation. It is generally not possible to test a unit’s overvoltage response to internal failure. Such test requires access to internal circuit nodes or the routing of such nodes to a test or output connector. In the absence of such test access, the overvoltage response test is limited to the unit’s response to an externally applied overvoltage fault. The following test methods are recommended:

a) Test Method a): For units with no overvoltage built-in-test (BIT) and independent output shutdown (multiple output units).
b) Test Method b): For units with overvoltage status BIT.
c) Test Method c): For units (or specific unit outputs) that result in shut down of all outputs in response to overvoltage.

Test Method a) For units with no overvoltage status BIT:

The circuit shown in Figure 3 is one test setup approach. If there are multiple outputs, the output that provides closed loop regulation, when subjected to over voltage, may cause other outputs to go low. Low voltage may in turn over ride the overvoltage signal providing a false representation. It is therefore necessary that the inter-relationships between the various outputs be determined prior to performing over voltage testing. Additionally, overvoltage protection circuits may independently shut down individual outputs on a multiple output supply or they may shut down the entire unit. For situations and/or units that result in complete shutdown in response to over voltage, test method c) is a preferred alternative.

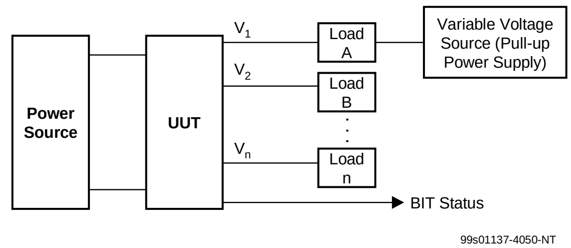

Figure 3. Overvoltage response test setup

For the particular output to be tested, reduce the load to the minimum, compatible with maintaining power supply specified tolerances. Increase the voltage on the variable voltage source to the specified overvoltage protection limit. Remove the variable voltage source and verify that the applicable Unit output is reduced to a safe level (normally zero). Alternatively the external pull-up supply can be increased in fixed increments, removing before each adjustment, so that the trip point can more precisely be determined. For latching type protection circuits the output shall remain at the trip level until input power is removed and reapplied or until some other means of overvoltage protection reset is activated. For units with a non-latching response to the overvoltage, the unit shall remain at the trip level for a pre-determined length of time and then recover to normal operation. For non-latching circuits the recovery time and overshoot/undershoot should be verified. This method may not apply to overvoltage response of all power supplies.

Test Method b) For units with overvoltage status BIT:

Connect the test setup shown in Figure 3; however, with the availability of an over voltage BIT status signal it is recommended that the external supply be slowly increased until the required overvoltage transition state occurs. Check at the transition point that the voltage level is within prescribed limits. Return the variable voltage source to the nominal value. Repeat the process for all outputs. Do not exceed the specified overvoltage trip point.

If the specified overvoltage trip limit is reached without status indication, remove the external supply and note whether a) the applicable output is within normal operating limits or b) the applicable output has been reduced to a safe level (normally zero). Condition a) indicates failure of the overvoltage protection circuit, condition b) indicates failure of the overvoltage BIT status circuit.

Test Method c) For units (or specific unit outputs) that result in shutdown of all outputs in response to overvoltage:

The test set-up of Figure 3 can again be used; however, with situations that result in complete unit shutdown it is recommended that the external supply be slowly increased until the required overvoltage transition occurs. The transition point can be determined by monitoring the current demand from the power source, or alternately with the use of a current probe on one of the input source leads. The input current demand should reduce to zero or a near zero quiescent level. Check at the transition point that the output voltage level on the output under test is within prescribed overvoltage limits. Return the variable voltage source to the nominal value and recycle the input power for latching type. Repeat the process for all outputs. Do not exceed the specified overvoltage trip point on any output.

Test Condition
Adjust the input voltage and load current to nominal specified value and over the specified operating temperature.

4. Two Examples from IEEE 1515

Example1: The first example is the specific case of output ripple mentioned in Section 2 above. This is covered in Section 4.5 of the standard. The text concerning output ripple measurement reads as shown previously.

There are two major components that contribute to the voltage ripple: switching ripple and commutation spikes. Switching ripple is due to the switching action of a UUT that happens at the switching frequency (or twice of it). Commutation spikes are due to commutations of currents from one device to another. It is related to the turn-on and turn-off speed of a device and hence they happen at a frequency that is typically 10 times of the switching frequency.

There are three test methods discussed in the text. All three methods are used in industry currently. The only thing the working group added is the test conditions to ensure uniformity.

Based on the discussion of the physics behind the ripple, it is apparent that measurement bandwidth needs to be specified together with amplitude of voltage ripple. It is hoped that when it comes to specifying ripple, one has to mention which method that is used and at what bandwidth the data is taken.

In the text the term "Period and Random Deviation" (PARD) was used. It is defined as the peak to peak value of the total ripple, including both components. This term was borrowed form a PSMA publication on terminology [2,3]. The term is loosely used, since the voltage ripple is definitely deterministic.

It is clear that if all the suppliers were using this test method, the confusion discussed in section 2 of this paper would have been avoided. In place of the multiplicity of test methods and conditions encountered in the example, a single test method would have resulted in directly comparable test results.

Example 2: The second example is the over voltage response as discussed in Section 4.15.2 of the standard. In drafting this parameter, the working group experienced heated debate. The issue was whether to include those methods that use internal circuitry to induce an overvoltage condition. Since 1515 is intended for manufacturers of power equipment, the working group settled down to a discussion on external method in induce overvoltage.

There are three test methods mentioned: units with no overvoltage status BIT, units with overvoltage BIT, and units (or specific unit outputs) that results in shut down of all outputs.

This parameter illustrates that even a simple parameter can have some subtleties when it comes to uniform definition and understanding of a particular parameter.

As previously mentioned, one of the key aspects of the new standard IEEE 1515 is that it defines language and test methods rather than attempting to standardize the performance of the parameters themselves. Consequently, there is no need for suppliers to redesign their equipment to meet the standard – rather, the standard can be immediately used to improve commonality and understanding in how the performance of the existing product is measured and specified.

In general, the more demanding the application and the more completely the product needs to be specified for that application, the more significant are the benefits. For high reliability and high performance power systems, it is essential to fully understand the characteristics and limitations of each element in the system. This means they must be designed, specified and tested using agreed upon, well-understood terminology, and test methods.

5. Benefits of Using IEEE 1515

A well-specified and agreed upon set of parameter definitions, test methods, and test conditions is of benefit to the power industry as a whole, including manufacturers, integrators and users of power products.

On the one hand, availability of accurate and well-understood specification information is critical to the user to allow a well-informed selection of the best product for the application. On the other hand, a product manufacturer needs accurate test results to enable the product to be fully characterized as part of his specification process.

Some of the most significant benefits from using the 1515 standard are summarized below.

Benefits for manufacturer:

- Reduces the need to develop and maintain in-house documentation describing test methods and conditions
- Reduces the likelihood of disagreement between supplier and customer regarding product specification or performance
- Gives an opportunity to improve customer understanding of, and confidence in, data sheet specifications
- Reduces the likelihood of differences and disagreements between different engineers or

different departments who are carrying out testing (e.g., between design and manufacturing groups, or between power designers and digital equipment designers)
- Reduces costs and improve customer acceptance.

Benefits for user and power system integrator:
- Reduces or eliminates the need to carry out extensive qualification testing on all potential suppliers' products
- Reduces the need to develop and maintain in-house documentation describing qualification test methods and conditions
- Reduces potential misunderstandings during specification and RFQ negotiation process with suppliers.
- May avoid the need for a costly and time-consuming redesign
- Reduces the need for custom design of product to suit application, since confidence in suppliers' existing standard product is increased
- Reduces costs and improve system availability. Again, the more completely the product must be specified, the more significant these benefits become.

Benefits for entry and mid-level engineers:
- Provides an in-depth discussion of many of the commonly used parameters
- Collects in a single place many of the prevalent test methods in industry

6. Continuing Effort of EPSS

Table I presents key features for IEEE 1515 and Table II shows those for the P1573 being developed.

While the IEEE 1515 focuses on parameters that are "internal" to a piece of power electronic equipment, a continuing effort by the EPSS will address corresponding issues at system level. This is a standardization of the parameters, interfaces and performance requirements for electronic power systems. It will be captured in a standard with the tentative designation: IEEE P1573 - "Recommended Practices for Electronics Power Subsystems: Parameters, Interfaces, Elements and Performance" (commonly referred to as P1573).

P1573 is currently being developed by the EPSS Working Group and is expected to be ready for publication in 2002.

The Working Group meets approximately four times a year, with the two most recent meetings being in October 2000 and concurrently with this APEC session. These meetings are open to all, and those who are interested are more than welcome to participate and to contribute.

Acknowledgement

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We are in debt to the members of the EPSS Working Group for their dedication and expertise. Without them, the IEEE 1515-2000 could not have been possible. Special thanks must go to the members of the balloting group. Their review has made this standard a better document.

For a copy of the IEEE Std 1515-2000, log on to
http://standards.ieee.org
http://standards.ieee.org/catalog/olis.
For a draft of P1573 (under development), log on to
http://grouper.ieee.org/groups/1515

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TABLE I SUMMARY OF IEEE STD 1515-200 CONTENT

SUBJECT AREA	1515 COVERAGE
Definitions of terms	Approximately 50 parameters in widespread use in the power industry are defined.
Electrical performance parameters	A definition of each parameter is given, together with a recommended test method and condition. Parameter groups include: DC voltage, AC voltage, Efficiency, Regulation, Ripple and spikes, Transients, Impedance, On/Off control, Isolation and grounding, Distortion, Conducted emissions, Susceptibility, Use of multiple power units in a system., Adjustments and control, and Fault protection
Reliability, maintainability, environmental and mechanical parameters	Parameters groups: Reliability, Maintainability, Environments, and Mechanical
General test practices and techniques	Test practices are described with emphasis on the practical aspects of testing such as lead configuration, data recording, accuracy, temperature measuring techniques and safety.

TABLE II SUMMARY OF IEEE PAR P1573 CONTENT

SUBJECT AREA	P1573 COVERAGE
Definitions of terms	A number of parameters in widespread use in the power industry are defined
Power system interfaces	Introduces the concept of four interfaces between system elements: electrical, mechanical, environmental and "system effectiveness"
Interface parameters	A definition of key parameters is given, with recommended test methods where appropriate. (In some cases, by reference to 1515.) Subjects covered are addressed under the four interfaces mentioned above.
Performance comparison	Commonly available performance is compared with the performance necessary to address high reliability or high performance segments of the power system market. Again, this is addressed under the four interfaces mentioned above.
Application guidelines	Information concerning power system design techniques, including system architecture selection, economic issues and system interaction. Methods for "adaptation" as a means to extend the specification limits of standard products and to allow their use in more severe environments.